Experimental studies of defect dynamics in complex (dusty) plasmas

Celine Durniak & Dmitry Samsonov

Dept. of Electrical Engineering and Electronics, The University of Liverpool, Liverpool, L69 3GJ, UK.
celine.durniak@liv.ac.uk

Complex plasmas consist of micron sized microspheres immersed into ordinary ion-electron plasmas. Similar to colloids, they can exist in solid, liquid or gaseous states and exhibit phase transitions. Complex plasmas are found in space: planetary rings, comets or interstellar clouds. In plasma technology, dust contamination has negative effects on the yield of semiconductor devices. The microparticles are charged negatively by the plasma. They strongly interact with each other electrostatically via a Yukawa potential. As the grains are weakly damped by gas friction and traceable individually, dynamic and nonlinear phenomena such as shocks, Mach cones, solitons, waves, elastic and plastic deformations can be observed at the kinetic level.

The experiments were performed in a capacitively coupled radio-frequency (rf) discharge. A powered lower electrode and a grounded ring upper electrode were placed in a vacuum chamber. A constant working pressure was maintained by a flow of argon. Monodisperse plastic microspheres were levitated in the sheath above the lower electrode. They were confined radially in a bowl shaped potential formed by a rim on the outer edge of the electrode and formed a monolayer hexagonal lattice. They were excited by voltage pulses applied to wires stretched above the electrode at approximately the same height as the particles. A horizontal thin sheet of laser light illuminated the particles, which were imaged by a digital video camera.

We performed a molecular dynamics (MD) simulation in order to support the experimental results. The molecular dynamics simulation code that we have developed solves the equations of motion for each microparticle moving in a global parabolic confinement potential and interacting with every other microparticle via a Yukawa potential [1]. The code is based on an object-oriented multi-threaded programming. It can be used to simulate various particle systems which can be characterised by interaction forces or potentials such as complex plasmas, colloids, granular media, plasma doping, ion beams, film growth, ion implantation. The equations of motion are solved using the fifth-order Runge Kutta method with the Cash Karp adaptive step size control. The ion-electron plasma is not explicitly included in the equations. The grains are damped by the friction force (equal to the neutral gas damping). We consider three- and two-dimensional (2D) systems of 3000 microparticles, which are first seeded randomly and the code is run until a crystalline structure is formed. Then different excitation forces are applied during a short time on the lattice.

We use an experimental model system (complex plasma) and MD simulation to study the dynamics of defects in 2D hexagonal lattices: dislocations or penta-hepta defects. We focus on their interactions with localized compressional waves in complex plasma crystals.

[1] C. Durniak, D. Samsonov, S. Zhdanov, and G. Morfill, EPL 88, 45001 (2009).